Government of Canada | Gouvernement du Canada
Canadian Forestry Service | Service canadien des forêts

The Douglas-fir tussock moth in British Columbia 1916-1984

J.W.E. Harris, A.F. Dawson and R.G. Brown

Information Report BC-X-268
Pacific Forestry Centre

86-0601/

The Douglas-fir Tussock Moth

in

British Columbia

1916-1984

J.W.E. Harris

A.F. Dawson

and

R.G. Brown

Canadian Forestry Service
Pacific Forestry Centre

BC-X-268

1985

The mention of certain formulations or product names does not constitute endorsement by the Canadian Forestry Service.

Canadian Forestry Service
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C.
V8Z 1M5

© Minister of Supply & Services Canada, 1985
ISSN 0705-3274
ISBN 0-662-14094-X
Cat. No. Fo46-17/268E

Abstract

The Forest Insect and Disease Survey annually detects, monitors and appraises defoliator infestations by measuring larval populations at a network of ground sampling stations and by observing defoliation from light aircraft. This report summarizes such observations on outbreaks of the Douglas-fir tussock moth, *Orgyia pseudotsugata*.

The Douglas-fir tussock moth is an important defoliator of Douglas-fir stands in the drier areas of southern British Columbia. Populations of this pest periodically increase sharply, persist for a few years, then suddenly decline. These high populations often cause tree mortality over limited, well-defined areas. Since 1916, eight outbreaks have occurred in one or more of 13 such locations within the dry subzone of the Interior Douglas-fir Biogeoclimatic Zone and its transition with the Ponderosa Pine-Bunchgrass Zone.

When tussock moth larvae are first noted in beating samples after several years of negative collections, localized areas of defoliation are likely to occur the following year. In the next year or two the infestation may expand and intensify, with tree mortality likely to occur at the center of outbreaks where severe defoliation is usually sustained. Localized defoliation often occurs on shade and ornamental trees near residences and farm buildings one or two years before outbreaks occur in forested areas.

Résumé

Le Relevé des insectes et des maladies des arbres permet de déceler, de surveiller et d'évaluer annuellement les infestations de défoliateurs grâce au dénombrement des populations de larves par le réseau de stations d'échantillonnage au sol et à l'observation de la défoliation à l'aide d'aéronefs légers. Ce rapport résume les observations concernant les infestations de la chenille à houppes du douglas (*Orgyia pseudotsugata*).

La chenille à houppes est un important défoliateur des peuplements de douglas taxifolié dans les régions sèches du sud de la Colombie-Britannique. Les populations de cet insecte suivent un cycle périodique: elles augmentent brusquement, demeurent stationnaires durant quelques années et déclinent soudainement. Lorsqu'elles sont denses, elles font souvent mourir les arbres dans des secteurs restreints et bien définis. Depuis 1916, il s'est produit 8 infestations dans un ensemble de 13 secteurs faisant partie de la sous-zone sèche de la zone biogéoclimatique intérieure peuplée de douglas taxifolié, ainsi que dans la zone de transition avec la zone peuplée de pin ponderosa et de schizaschyrium à balais.

Lorsque des larves de la chenille à houppes sont observées pour la première fois, après plusieurs années d'absence, dans les échantillons obtenus par battage, on peut s'attendre à une défoliation locale l'année suivante. Un ou deux ans après, l'infestation peut s'étendre et s'intensifier, et une mortalité des arbres peut survenir au coeur des infestations où la défoliation demeure habituellement sévère. Il arrive souvent qu'il se produise, un ou deux ans avant l'infestation des régions boisées par la chenille à houppes, une défoliation localisée des arbres d'ombrage et d'ornement près des résidences et des bâtiments de ferme.

Introduction

The Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera: Lymantriidae), was first reported causing damage in British Columbia (B.C.) in 1916 near Chase. Since then, there have been several outbreaks in the southern interior of the Province, resulting in considerable top-kill and mortality of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Populations of the tussock moth build up to outbreak levels quickly, remain at damaging levels for a few years, and then suddenly collapse. Between infestations, there are years when few or no larvae are collected in routine sampling for defoliators over most of the range of the tussock moth.

The tussock moth has one generation per year, overwintering in the egg stage. Eggs hatch in spring and young larvae feed on new needles causing them to dry out and die, which gives the tree a reddish cast. Older larvae feed on both new and old foliage, mature in late summer, then spin cocoons on the host foliage or bark. Adult females cannot fly and remain on their cocoons, where, after mating, they lay eggs in a conspicuous mass.

Tussock moth larvae, when numerous, may completely defoliate and kill trees in a single growing season. In B.C., Douglas-fir is the preferred host, but during outbreaks other conifer species may be attacked. Usually the upper third of the crown is defoliated first, which may result in top-kill and stag-headed trees. Tree mortality is more common after two or more successive years of complete defoliation. Open-grown trees about farm buildings and towns are attacked as well as close-grown pole-sized stands of Douglas-fir. Trees of all age classes may be attacked, including seedlings and saplings. Trees weakened by defoliation may exhibit reduced growth and may succumb to attack by Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins.

Because tussock moth females are flightless, first-instar larvae disperse by becoming windborne on silk threads. This results in scattered discrete spots of discolored trees noticeable in the first year of attack. In the following year, the trees around the spots may become defoliated creating a 'halo-effect,' i.e., a patch of previously defoliated grey trees surrounded by a ring of discoloration (Shepherd 1977). These patches may coalesce to form larger areas of defoliation.

Defoliation of Douglas-fir by the tussock moth has been limited to drier areas of southern B.C., except for the dry belt area of the East Kootenay. Shepherd (1977) classified the tussock moth as "Nonspreading — Zone Restricted" with infestations confined to the dry subzone of the Interior Douglas-fir Biogeoclimatic Zone (U.B.C. Faculty of Forestry 1983) and the ecotone (transition) between this Zone and the Ponderosa Pine-Bunchgrass Zone in the Thompson, Okanagan, Similkameen, and Kettle valleys. Tree damage has also occurred in the Coastal Douglas-fir Zone near Vancouver, Victoria and Nanaimo from 1967 to 1972 and from 1981 to 1983. High populations have also occurred in the Lillooet area and in some wet belt areas such as Arrowhead and Glacier National Park.

Defoliator numbers, and the damage they cause, are monitored annually throughout B.C. by the staff of the Forest Insect and Disease Survey (FIDS) of the Canadian Forestry Service. Prior to 1949, population records were largely estimates based on observations made without a particular sampling plan. In 1949, population numbers began to be measured by FIDS staff at a ground network of permanent sampling stations. Counts from various stations were combined, averaged, and plotted to show population fluctuations over time. Observations of tree defoliation and mortality have continued to the present with increased precision, as more use has been made of aircraft for detecting and appraising damage (Harris and Dawson 1979).

This report brings together published and unpublished information on the history of Douglas-fir tussock moth infestations in B.C. as recorded by FIDS. It summarizes tree damage since 1916 and larval populations since 1949, when data on the latter began to be collected on a regular basis. The average number of larvae and the percentage of positive samples were calculated and plotted for four geographic areas where major infestations had occurred so that population changes could readily be seen.

Methods

Information on the Douglas-fir tussock moth in British Columbia was obtained from various published and unpublished records starting from 1916. Quantitative larval data were retrieved from the FIDS computer data file (Harris 1976) for the period from 1949 to 1984.

The most important literature sources were the FIDS annual regional and national (Canadian Forestry Service 1937-1984) reports which summarize forest pest conditions in B.C.[1] For the period 1923 to 1967, the *Canadian Insect Pest Review* was also consulted (Scientific Information Section, Research Branch, Canada Agriculture). McDunnough (1921) and Balch (1932) described the earliest infestations, and Sugden (1957) outlined most of the infestations up to 1956.

Populations of Douglas-fir tussock moth larvae were determined annually from records collected by FIDS at 40 permanent sampling stations (Fig. 1), using the 3-tree beating method (Harris 1976). In this method, a 2.7-m pole was used to beat larvae from branches of three Douglas-fir trees at each station onto a 2.1-m × 2.7-m sheet spread beneath each tree. The average numbers of tussock moth larvae per sample and the percentage of Douglas-fir samples containing larvae were calculated for each year from 1949 to 1984 for sampling stations within each of four geographic study areas (Fig. 1, A-D) in which one or more of four infestations had occurred between 1949 and 1984. The study areas were selected on the basis of the historical pattern of defoliation by the tussock moth since 1949, and consisted of groups of drainages for which sufficient data to draw reliable conclusions were available. The population figures were graphed by year for each area to show population fluctuations. The four study areas were:

Fraser — Thomson: Fraser River between Lytton and Pavilion; Thompson River from Lytton to Savona; Bonaparte River from Ashcroft to Clinton.

Kamloops — Chase: North and South slopes of Kamloops Lake; North Thompson River from Kamloops to Darfield; South Thompson River from Kamloops to Squilax; along Hwy. 97 from Monte Creek to Westwold.

North Okanagan — Shuswap: From the Salmon Arm — Falkland — Armstrong area south along Okanagan Lake to Kelowna and Westbank.

South Okanagan — Similkameen: From Summerland to Osoyoos; Similkameen River from Keremeos to Princeton; Olalla — Yellow Lake area.

History of outbreaks

Douglas-fir tussock moth larval populations increased to infestation levels at one or more of 13 locations in the southern interior of B.C. (Figs. 2 and 3) eight times between 1916 and 1984 (Fig. 4). These infestations varied in intensity from high populations only, to high populations with visible defoliation[2] and tree mortality. Outbreaks occurred at intervals of 7 to 12 years and lasted for 4 to 6 years before subsiding. The infestations are described below in greater detail based on defoliation data for the period from 1916 to 1984, and on larval numbers for the period from 1949 to 1984. For two of the locations (Merritt and Kettle River), larval populations were too localized and there were not enough sampling stations for analysis. The remaining eleven locations fell into the four study areas in which major outbreaks had occurred since 1949, when larval sampling was initiated.

---

[1] a. "Annual District Reports, Forest Insect and Disease Survey, British Columbia 1920-1978" and "Forest Insect and Disease Conditions in British Columbia 1979-1984" (an annual file or internal report, by Forest Region). Request by geographic area of interest and year. Limited numbers of copies of some years available for loan. By Canadian Forestry Service, Pacific Forestry Centre, Victoria, B.C.

b. "Annual Report of the Forest Insect and Disease Survey" (Canada-wide annually since 1937), Canadian Forestry Service, Ottawa. Request by year.

[2] The criteria used by FIDS to classify defoliation from the air were as follows:- **light**: discolored foliage barely visible from the air, some branch tip and upper crown defoliation; **moderate**: pronounced discoloration, noticeably thin foliage, top third of many trees severely defoliated, some completely stripped; **severe**: bare branch tips and completely defoliated tops, most trees more than 50% defoliated.

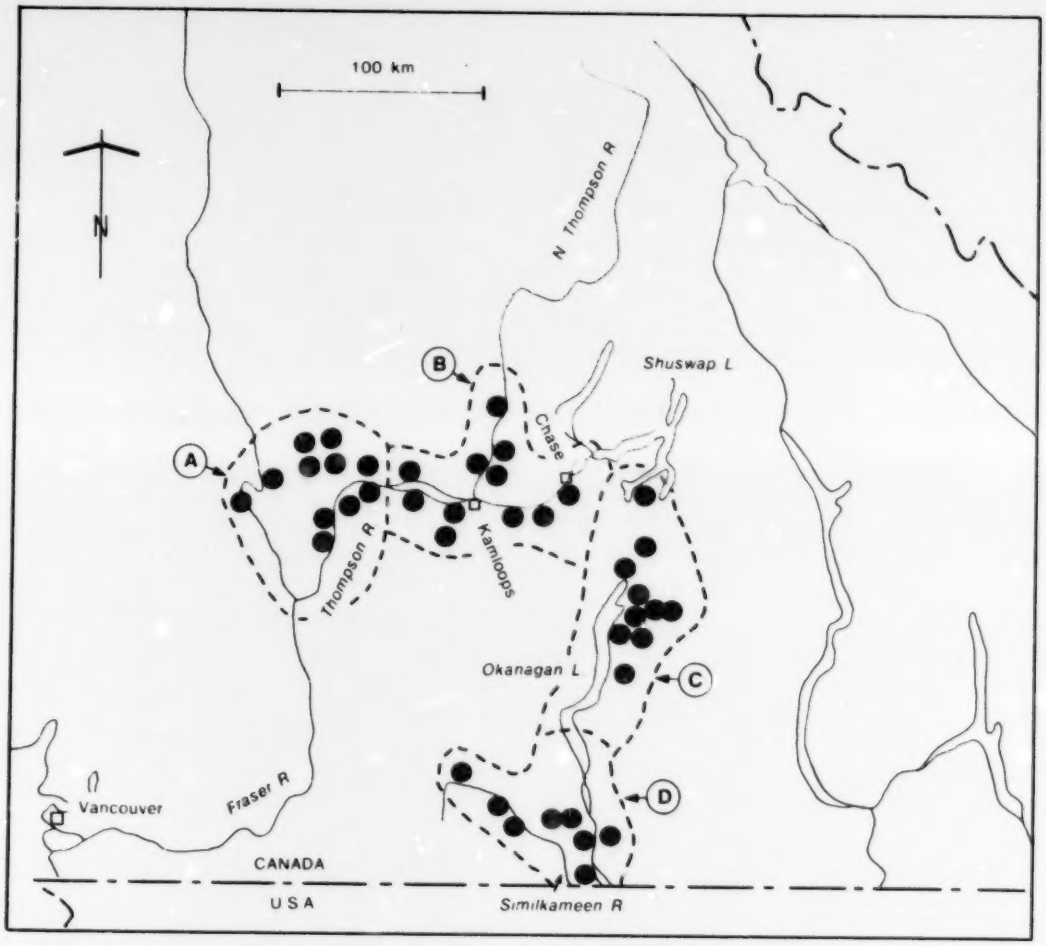


Fig. 1. Douglas-fir tussock moth Forest Insect and Disease Survey permanent sampling stations (●) in the southern interior of British Columbia for major study areas A-D. Samples in each area were combined to determine average numbers of larvae per sample and the percentage of positive samples, 1949-1984. Study area A: Fraser — Thompson; study area B: Kamloops — Chase; study area C: North Okanagan — Shuswap; study area D: South Okanagan — Similkameen.

1916-1921

The first outbreak was recorded in 1916, when the tussock moth defoliated Douglas-fir at Chase on the South Thompson River. In 1917, there was tree mortality at Chase and localized severe defoliation at Hedley in the Similkameen Valley (Fig. 4a). The infestation continued at both locations in 1918 with new areas of defoliation noted at Salmon Arm and Armstrong. In 1919, the infestation continued at Chase and Armstrong, with new areas of defoliation occurring at Vernon and Kamloops Lake. Douglas-fir and ponderosa pine (*Pinus ponderosa* Laws.) were severely defoliated. In 1920, the tussock moth remained active between Vernon and Kelowna and in marginal stands near Kamloops Lake, but populations declined elsewhere. The infestation continued in 1921 at Kamloops Lake and Chase and from Vernon to Kelowna. Completely defoliated trees had died, especially reproduction, sapling and pole-sized Douglas-fir. The upper third of

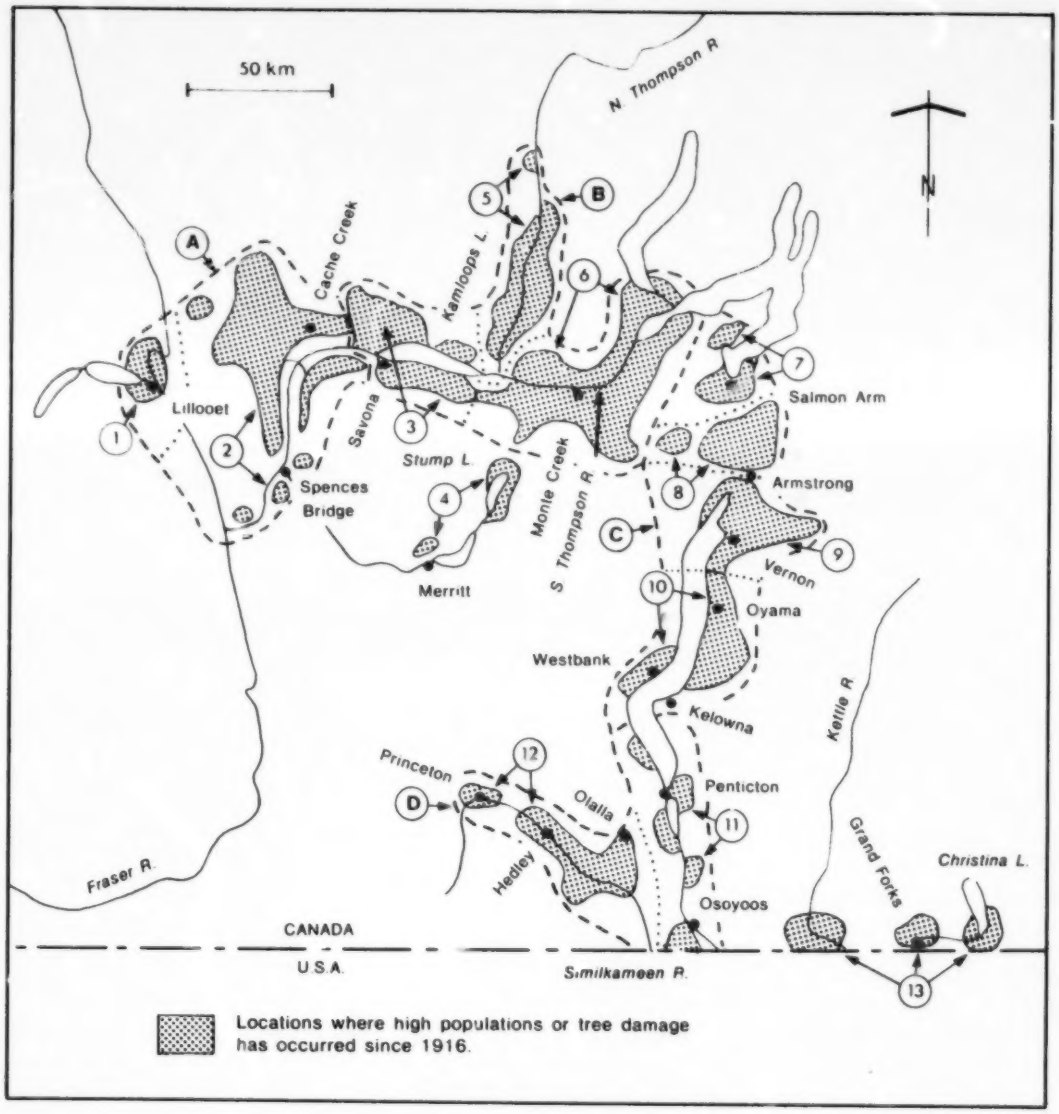


Fig. 2. Distinct Douglas-fir tussock moth outbreak locations (1-13) in the southern interior of British Columbia, 1916-1984 (see also Fig. 3). A-D identify major study areas from which permanent sampling station records were extracted and averaged from 1949-1984 (see Fig. 1).

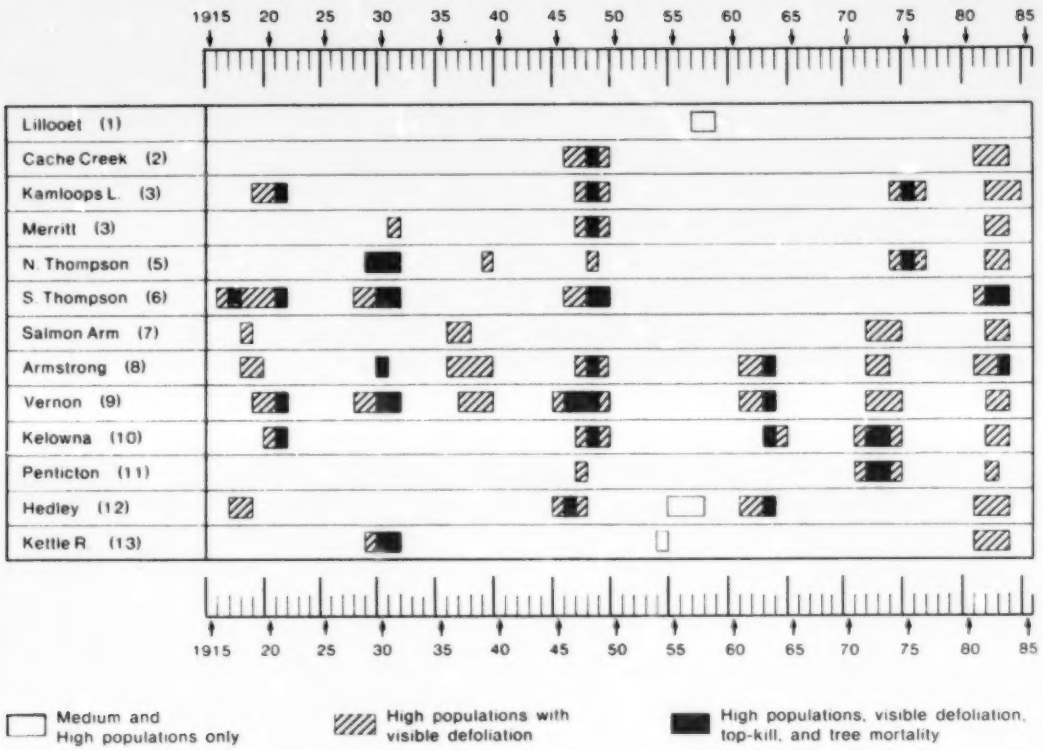

1915 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Lillooet (1)
Cache Creek (2)
Kamloops L. (3)
Merritt (3)
N. Thompson (5)
S. Thompson (6)
Salmon Arm (7)
Armstrong (8)
Vernon (9)
Kelowna (10)
Penticton (11)
Hedley (12)
Kettle R. (13)
1915 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Medium and High populations only
High populations with visible defoliation
High populations, visible defoliation, top-kill, and tree mortality

Fig. 3. Infestations of Douglas-fir tussock moth in the southern interior of British Columbia, 1916-1984 (locations 1-13 correspond to those in Fig. 2).

the crown was killed on semi-mature and mature trees that were severely defoliated. The infestation collapsed in 1922 due to heavy larval mortality, the cause of which was unknown.

1928-1931

In 1928, localized areas of defoliation were reported near Kamloops, Pritchard and Vernon adjacent to ranch buildings. A few trees were 90% defoliated. In 1929, defoliation increased at Vernon and new areas occurred along the South Thompson River at Chase and Little Shuswap Lake, in the Kettle River Valley at Kettle Valley and Cascade, and near Heffley Creek along the North Thompson River, where young trees were killed over 40 ha (Fig. 4b). In 1930, the infestation expanded considerably, especially in open forest, ranging from 1 to 400 ha in the following locations: Deep Creek north of Armstrong; near Vernon; in the Kettle River Valley at Grand Forks and Kettle Valley; along the South Thompson River at Chase, Squilax, Little Shuswap Lake, Paul Lake and Ducks Range; and in the North Thompson Valley. Tree mortality and top-kill were extensive. In 1931, the infestation again expanded, with new areas of defoliation at Vernon, Merritt and Stump Lake and in the South Thompson drainage at Campbell Creek, Knutsford, Barnhart Vale, and Westwold. Hot weather caused heavy larval mortality at Okanagan Landing near Vernon. Grey patches of dead trees were visible in the center of defoliated areas. Populations subsided almost completely in 1932 from unknown causes.

1936-1939

In 1936, defoliation occurred in localized areas around farms near Armstrong and Salmon Arm,

and new areas of defoliation appeared near Armstrong and Vernon in 1937 (Fig. 4c). The area near Salmon Arm was sprayed with lead arsenate. In 1938, the infestation expanded on trees around farms and towns in open forest. Severe defoliation occurred near Vernon and Armstrong. Moderate defoliation occurred in 1939 at Lavington, Armstrong, Vernon, Okanagan Landing, Larkin and along the North Thompson River Valley, but populations collapsed in all areas as larvae were killed by a virus disease.

1945-1949

Defoliation occurred in localized areas in 1945-1946 at Vernon, and at Hedley in the Similkameen Valley. In 1946, tree mortality occurred and new areas of defoliation appeared near Cache Creek and the South Thompson River at Monte Lake, and in the Similkameen Valley at Princeton (Fig. 4d). Trees were completely defoliated at Monte Lake. In 1947, spots of defoliation occurred from the Cache Creek and Kamloops Lake areas south through the Okanagan Valley to Osoyoos. Severe defoliation occurred in the South Thompson Valley near Chase, Squilax, Pritchard, Monte Creek, and Monte Lake, at Stump Lake near Merritt, Oregon Jack Creek near Cache Creek, at Hedley, Armstrong, and at Vernon where many trees were killed. Severe defoliation also occurred in 1948 at many of the above locations, particularly at Oregon Jack Creek (1600 ha) and Monte Creek (1300 ha). Mortality of Douglas-fir and ponderosa pine occurred at all locations. Light defoliation occurred in the North Thompson Valley near Heffley Creek and at Paul Lake northwest of Kamloops. Larval mortality was heavy due to a virus disease and parasitism and in 1949 the infestation subsided, but defoliation ranged from 10 to 100% near Kamloops Lake at Savona, Criss Creek and Clemes Creek. Light defoliation occurred in other locations, then populations collapsed. Heavy mortality of young Douglas-fir and ponderosa pine occurred along the South Thompson River at Monte Creek-Ducks Range where most of the larger trees had their tops killed.

1954-1958

In 1954, a small infestation was detected at Cascade in the Kettle River Valley (Fig. 4e) but it subsided in 1955 due to a virus disease. In 1955, a light infestation was discovered near the Similkameen River at Olalla which subsided due to an unknown disease in 1956. In 1956-1957, light populations were present in the same locality at Long Mountain and near Yellow Lake. In 1957, moderate populations occurred near Lillooet at Cayoosh Creek, Bridge River and Pavilion, and at Seton Lake in 1958, but populations subsided in 1959.

In the Fraser-Thompson area (Figs. 4e and 5), larval populations peaked at 16 and the percentage of positive samples peaked at 33% in 1958, while in the South Okanagan-Similkameen area (Figs. 4e and 5), larval populations peaked at 34 and the percentage of positive samples peaked at 33% in 1956.

1961-1964

In 1961, an outbreak started in the North Okanagan and populations also increased in the Similkameen Valley. Defoliation was observed in farmlands on single trees or groups of open-grown trees near Armstrong and Vernon and in dense pole-sized Douglas-fir stands up to 8 ha at the north end of Okanagan Lake. In 1962, the infestation increased and intensified but virus disease was widespread and some populations collapsed. Severe defoliation occurred at Armstrong and localized defoliation at Vernon, Lavington, Larkin and Irish Creek, and from Keremeos to Hedley in the Similkameen River Valley (Fig. 4f). Ornamental blue spruce (*Picea pungens* Engelm.) were also attacked in Armstrong. During 1963, extensive defoliation occurred between Keremeos and Hedley and near Vernon at Kalamalka and Okanagan lakes. Top-kill occurred on trees defoliated for two years in all these areas. Moderate to severe defoliation over smaller areas occurred at Armstrong and Otter Lake, and near Vernon at Goldstream, BX District, and Lavington, and at Oyama and Ellison Lake near Kelowna, with isolated patches near the Similkameen River at Ashnola River and Olalla. High larval mortality resulted from polyhedral virus and starvation. In 1964, populations collapsed in the Okanagan-Similkameen valleys, but localized defoliation continued at Ellison Lake. Stands that had been defoliated for two years suffered up to 50% mortality though recovery was good in the Similkameen Valley.

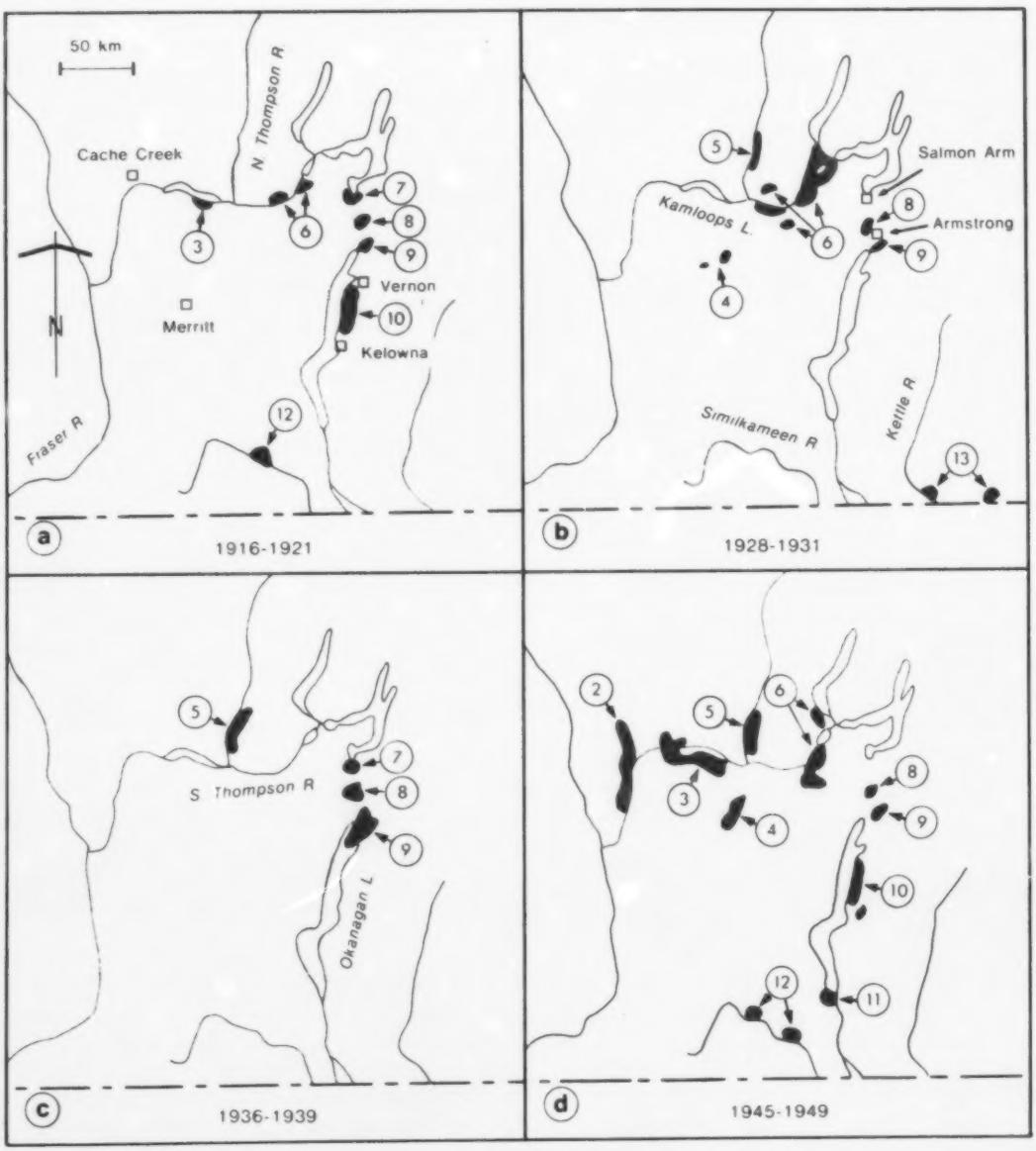
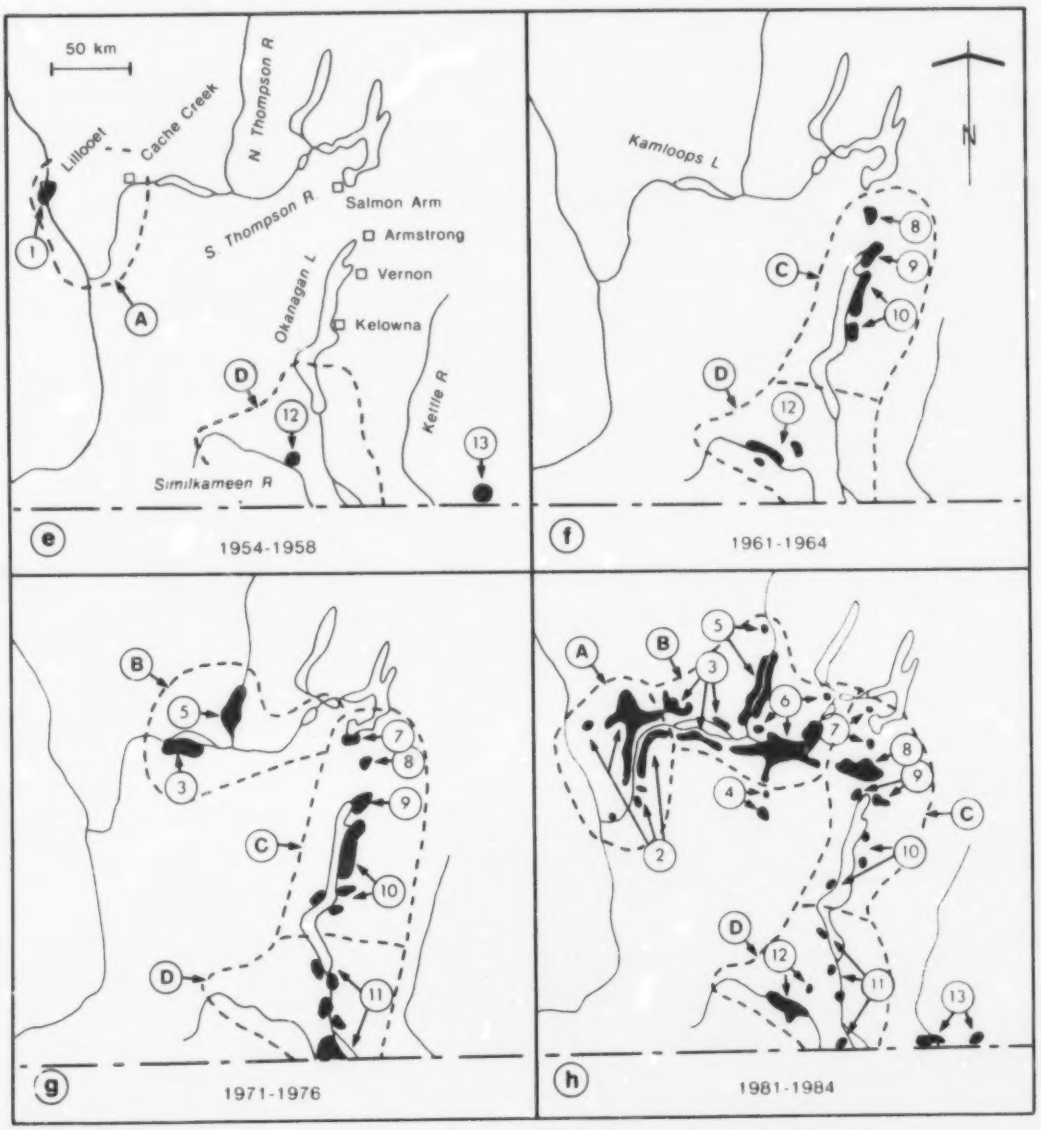


Fig. 4. Infestations of Douglas-fir tussock moth in the southern interior of British Columbia, 1916-1984 (A-D are study areas described in Fig. 1). (continued on page 11)

In the North Okanagan-Shuswap area (Figs. 4f and 5), the average number of larvae per sample rose from near zero in 1960 to 28 in 1961, the first year defoliation occurred in the area. The percentage of positive samples rose from 0% to 88%. The average larval count peaked at 78 and the percentage of positive samples peaked at 100% in 1962, then both dropped to zero in 1965.

In the South Okanagan-Similkameen area (Figs. 4f and 5), larval populations rose from 3 in 1961 to 6 in 1962, when defoliation first occurred in the area. The percentage of positive samples rose slightly from 43% to 50%. Both figures peaked in 1963 at 48 and 100%, respectively, then dropped to zero in 1965.



(Fig. 4 continued)

1971-1976

In 1971, defoliation occurred near Kelowna at Oyama, Winfield, Glenmore, and Westbank and in the South Okanagan at Kaleden, with up to 90% defoliation of semi-mature and understory Douglas-fir and ponderosa pine (Fig. 4g). The infestation expanded in 1972 to over 700 ha from Salmon Arm to Osoyoos, with most of the defoliation near Kelowna. Tree mortality occurred in the center of some locations previously defoliated. In 1973, the infestation expanded in the Kelowna area with severe defoliation over 2070 ha and 400 ha of recorded tree mortality. Defoliation also occurred at Savona, Salmon Arm, Vernon, Okanagan Falls, and Penticton. By late summer, nuclear polyhedrosis virus disease was present in the Okanagan Valley, causing populations to collapse in several locations, especially at Osoyoos where over 20 ha of tree mortality and 40 ha of top-kill occurred. In 1974, light to moderate defoliation occurred on 230 ha in eight small areas near Salmon Arm, Vernon, Kelowna, and Penticton. In 1975, populations completely collapsed.

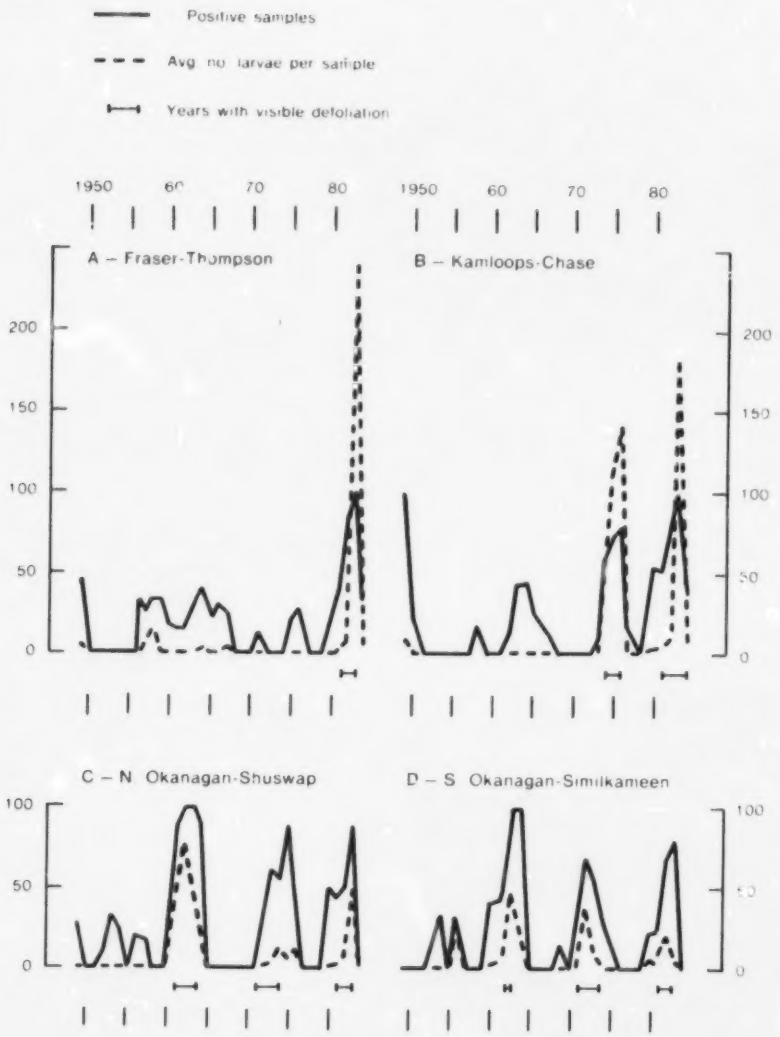


Fig. 5. Average annual Douglas-fir tussock moth larval populations on Douglas-fir in the southern interior of British Columbia for study areas A-D, 1949-1984.

In 1974, Douglas-fir tussock moth severely defoliated immature Douglas-fir and some ponderosa pine along the south side of Kamloops Lake on 325 ha, and in combination with the western false hemlock looper, on 3000 ha along the North Thompson River. The infestation expanded in both locations in 1975 and severe defoliation continued. There was considerable mortality of trees previously attacked. Late instar larvae were infected with a virus disease and egg counts were considerably lower than the previous year.

In 1975, over 12 140 ha of Douglas-fir forest were sprayed with the bacteria, *Bacillus thuringiensis*, resulting in reduced larval populations. In 1976, 7870 ha were sprayed with acephate, but severe defoliation occurred on 1780 ha beyond the spray boundaries. A virus disease of the late larval stages caused populations to collapse in 1976.

In the Kamloops-Chase area (Figs. 4g and 5), the average number of larvae per sample rose sharply

from 1 in 1973 to 62 in 1974, when defoliation was first recorded in the area. The percentage of positive samples rose from 10% to 55% in the same period. The average larval count peaked at 141 and the percentage of positive samples peaked at 78% in 1976; both figures then dropped to 0 in 1978. In the North Okanagan-Shuswap area (Figs. 4g and 5) the population figures were much lower; the average number of larvae per sample was 0 in 1971, when defoliation was first recorded in the area, and rose to 2 the next year. The percentage of positive samples rose from 0 to 14% in the same year. The average larval count peaked at 14 in 1974, and the percentage of positive samples peaked at 88% in 1975. Both dropped to zero in 1977. In the South Okanagan-Similkameen area (Figs. 4g and 5) the average larval count and the percentage of positive samples were both zero in 1970, and rose to 2 and 29%, respectively, in 1971, when defoliation first became visible in the area. The larval count peaked at 38 and the percentage of positive samples peaked at 71% in 1972, then both dropped to zero in 1976.

1981-1984

In 1980, notable increases in tussock moth populations occurred in the Lillooet-Ashcroft-Kamloops area and in the Shuswap, Okanagan, and Similkameen valleys. In 1981, over 1080 ha of immature and mature Douglas-fir stands were defoliated at 20 spots along the South Thompson River from Monte Creek to Niskonlith Lake, in the Falkland-Armstrong area, at Carquille and Scottie Creek near Cache Creek, in the Similkameen Valley near Hedley, and at Christina Lake in the Kettle River drainage (Fig. 4h). Severe defoliation occurred on 650 ha in the South Thompson Valley from Monte Creek to Pritchard and at Glenemma near Armstrong; other areas suffered only moderate defoliation. At Scottie Creek and near Armstrong, naturally occurring nuclear polyhedrosis virus was present in the late-instar larvae. Infested stands in the Similkameen Valley near Hedley were sprayed with a nuclear polyhedrosis virus which prevented larvae and pupal development and resulted in a very low number of female cocoons with egg masses.

In 1982, the infestation expanded considerably and 12 770 ha of light to severe defoliation were recorded. Expansion occurred in the Cache Creek, South Thomson Valley, Armstrong, Similkameen, and Kettle Valley areas, with new areas of defoliation in the Kamloops Lake, North Thompson River, Salmon Arm, Vernon, Kelowna, and South Okanagan areas, at Stump Lake near Merritt, and Rock Creek in the Kettle Valley. Nuclear polyhedrosis virus was present in stands near Armstrong, Chase, and Hedley. Tree mortality and top stripping occurred in stands where defoliation was severe between Pritchard and Monte Creek, along the South Thompson River. At Christina Lake, 20 ha were aerially sprayed with Orthene, and although larval populations remained high, few egg masses were later found. Near Cache Creek at Veasy Lake, an experimental spray of naturally occurring nuclear polyhedrosis virus reduced populations by 60% to 93% compared to check plots. Near Chase, a 120 ha stand was aerially sprayed with Sevin-4 ® Oil during larval dispersion. This treatment successfully controlled a potentially damaging population and no defoliation occurred in 1982.

In 1983, there was a further expansion of the outbreak with 23 450 ha of mostly severe defoliation recorded. In the South Thompson and Armstrong locations, in areas previously defoliated, there were 4750 ha of grey stands (those in which trees are either dead or appear to be dead but which may recover). The infestation decreased in the Okanagan-Similkameen area and at Christina Lake, but intensified in other areas with the greatest expansion in the North Thompson River Valley north to Barriere and in the Kettle Valley at Rock Creek, with new areas near Spences Bridge, Savona, Pavilion and Lumby. However, a high incidence of naturally occurring nuclear polyhedrosis virus affecting larvae and of parasitic flies in cocoons, as well as low egg mass counts, indicated that a major decline of the infestation would occur. In 1984, there were only 50 ha of light defoliation and 110 ha of severe defoliation recorded near Kamloops on the south side of Kamloops Lake. There were 5500 ha of grey stands mapped in previously defoliated locations, mostly in the Cache Creek area and from Kamloops east to Pritchard. Populations collapsed in most areas, with only a few collections containing larvae.

Between 1981, when defoliation first became visible, and 1983, the average numbers of larvae per sample in the Fraser-Thompson and Kam-

loops-Chase areas (Figs. 4h and 5, study areas A and B) rose from 1 and 2, respectively, to 239 and 180, respectively—the highest levels ever. Over the same period, the percentage of positive samples in the Fraser-Thompson and Kamloops-Chase areas rose from 43% and 50%, respectively, to 100%. Between 1981 and 1983 in the North Okanagan-Shuswap area (Figs. 4h and 5, study area C), the average number of larvae per sample rose from 2 to 50, and the percentage of positive samples rose from 43% to 88%. In the South Okanagan-Similkameen area (Figs. 4h and 5), the average larval count peaked at 23 in 1982, and the percentage of positive samples peaked at 80% in 1983.

Discussion

Tussock moth populations periodically increase to infestation levels, cause localized defoliation, top-kill and tree mortality for 1 to 3 years, and then decline. Eight such outbreaks have been recorded since 1916, and three have occurred since tree-beating for larvae began in 1949 (high populations also occurred in 1954-1958 but there was no visible defoliation). In six of the nine instances of population rise examined (Fig. 5), the average numbers of larvae per sample ranged from 0.5 to 7 in the year preceding visible defoliation and the percentage of positive samples ranged from 10% to 55%. In the year when defoliation was first visible, the average larval count ranged from 1 to 62 and the percentage of positive samples ranged from 25% to 55%, and for the peak years the figures were 23 to 239, and 78% to 100%, respectively. The figures dropped to zero 1-2 years after the last year of visible defoliation. In the other three instances, the figures were zero the year before the first visible defoliation, the average numbers of larvae per sample ranging from 1 to 28 in the first year of defoliation, and the percentage of positive samples ranged from 29% to 88% (except in area C, where there were no positive samples). The figures peaked at 14 to 78 and 71% to 100% before dropping to zero 1-3 years later.

The location, extent, and intensity of defoliation of Douglas-fir stands by the tussock moth is estimated annually by FIDS during aerial or ground surveys, usually in mid-summer at the height of foliage discoloration. Larval populations are measured in early summer at a network of permanent ground sampling stations established within the host type, where ground access permits.

To be useful in determining infestation trends, such as impending outbreaks, sampling stations should be located where tussock moth populations are developing and defoliation occurs (Shepherd *et al.* 1984). However, while every effort is made to locate stations in representative stands, the population parameters determined at these stations do not always reflect active tussock moth populations or defoliation. Thus, as noted above, data from all the stations in major drainages could indicate a zero population level even though defoliation has occurred at least somewhere in these drainages. This may happen since rising populations are often localized and do not occur everywhere within the host stand type, because the females are wingless and dispersion is chiefly by windblown larvae from an infection center. In the later years of an infestation, populations and defoliation are usually more widespread. Also, defoliation and populations may shift around within an infestation and occur in different stands in different outbreaks, while sampling stations are fixed. Nevertheless, if enough representative stations are included in an area, they should reflect defoliation and population outbreak trends adequately, and reduce the effect of stations where populations remain low. If sampling stations show consistently low or zero populations, however, they should be relocated.

Populations often reach outbreak proportions from endemic levels in a single year, so there may be little warning of impending damage. Usually, however, localized outbreaks occur on ornamental or shade trees in residential settings a year or two before outbreaks occur in nearby forested areas, thus providing some warning. When larvae are first found in samples after several years of negative collections there is a strong possibility of an outbreak occurring. Localized defoliation is likely to occur the same or the following year, and severe defoliation and tree mortality are likely one to two years later.

Sampling should therefore concentrate on locations where high larval numbers were collected and visible damage was recorded, especially where defoliation has recurred during more than one infestation period (Fig. 6).

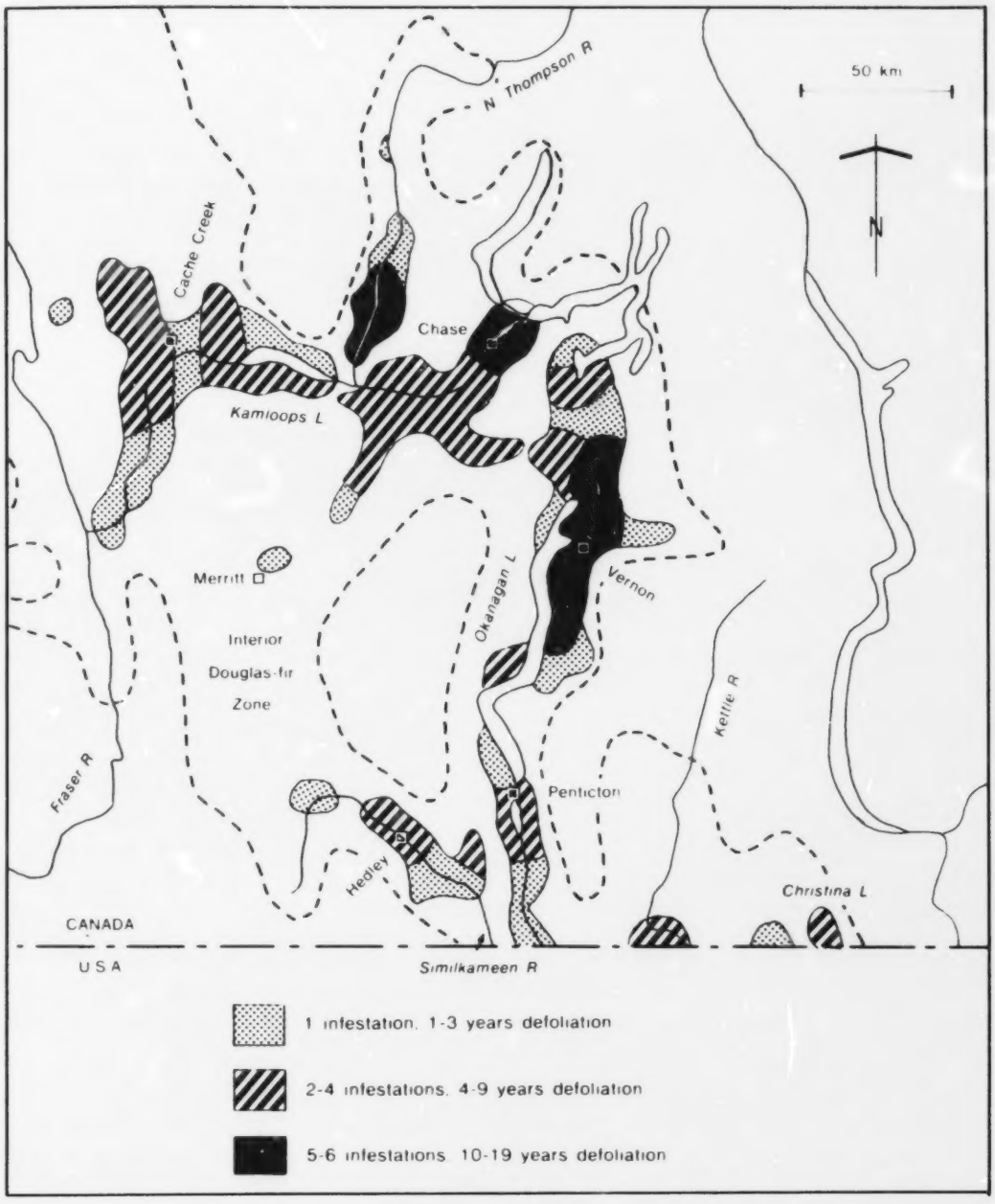


Fig. 6. Locations most likely to have Douglas-fir tussock moth infestations in southern interior British Columbia, rated by the number of infestations and years of defoliation that have occurred since 1916.

References

Balch, R.E. 1932. The fir tussock moth (*Hemerocampa pseudotsugata* McD.). J. Econ. Ent. 25: 1143-1148.

Canadian Forestry Service. 1937-1984. Annual Report of the Forest Insect and Disease Survey. Canadian Forestry Service, Ottawa.

Harris, J.W.E. 1976. Storage and retrieval of quantitative British Columbia-Yukon Forest Insect and Disease Survey records. Can. For. Serv. Pac. For. Res. Cent. Inf. Rep. BC-X-120, 30 p.

Harris, J.W.E. and A.F. Dawson. 1979. Evaluation of aerial forest pest damage survey techniques in British Columbia. Can. For. Serv. Pac. For. Res. Cent. Inf. Rep. BC-X-198, 22 p.

McDunnough, J. 1921. New British Columbia tussock moth, *Hemerocampa pseudotsugata*. Can. Ent. 53: 53-56.

Shepherd, R.F. 1977. A classification of western Canadian defoliating insects by outbreak spread characteristics and habitat restriction. Insect Ecol. Agric. Exp. Sta. U. Minn. Tech. Bull. 310: 80-88.

Shepherd, R.F., I.S. Otvos and R.J. Chorney. 1984. Pest management of Douglas-fir tussock moth (Lepidoptera: Lymantriidae): a sequential sampling method to determine egg mass density. Can. Ent. 116: 1041-1049.

Sugden, B.A. 1957. A brief history of outbreaks of the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., in British Columbia. Proc. Ent. Soc. B.C. 54: 37-39.

U.B.C. Faculty of Forestry. 1983. Forestry Handbook for British Columbia 4th Edition. U.B.C. Undergraduate Society, Vancouver, B.C. 611 p.